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(71) Applicant (*for all designated States except US*): **HALLIBURTON ENERGY SERVICES, INC.** [US/US]; Building 1, 6th floor, 4100 Clinton Drive, Houston, TX 77020 (US).

(72) Inventors; and

(75) Inventors/Applicants (*for US only*): **HOOPER, Michael** [US/US]; 6519 Allentown, Spring, TX 77389 (US). **JEREBEK, Alois** [AT/US]; 805 Bayou River Drive, Houston, TX 77079 (US). **RINGGENBERG, Paul, D.** [US/US]; 5906 Sandy Pine Court, Spring, TX 77379 (US). **PALUCH, Bill** [US/US]; 8014 Summer Trail, Houston, TX 77040 (US).

(74) Agent: **GILBRETH, J., M. (Mark)**; Gilbreth & Associates, P.C., P.O. Box 61305, Houston, TX 77208-1305 (US).

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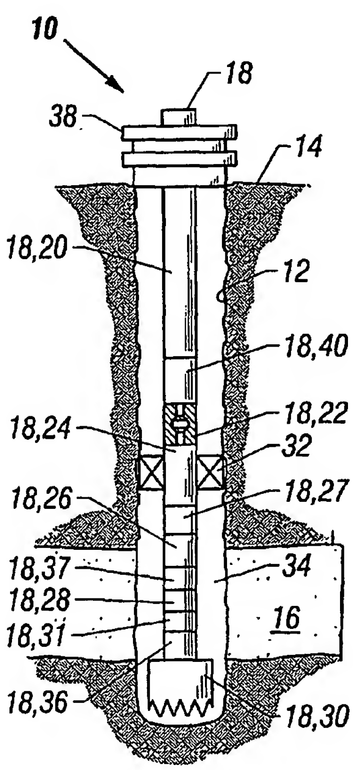
(54) Title: DRILLING FORMATION TESTER, APPARATUS AND METHODS OF TESTING AND MONITORING STATUS OF TESTER



(57) Abstract: Integrated drilling and evaluation systems and methods for drilling, logging and testing wells are provided. The drilling and evaluation systems are basically comprised of a drill string (18), a drill bit (30) carried on a lower end of the drill string (18) for drilling a well bore, logging while drilling apparatus (28) included in the drill string (18) for identifying subsurface zones or formations of interest, packer means (32) carried on the drill string above the drill bit for sealing a zone or formation of interest below the packer means (32), a fluid testing means (26) included in the drill string (18) for controlling the flow of well fluid from the zone or formation of interest into the drill string (18), a function status monitor included in the drill string (18) to evaluate the capacity of the various test instruments to function, and a function timer (31) included in the drill string (18) to automatically sequence the steps of the various test procedures. The drilling and evaluation systems and methods for using the systems allow one or more subsurface zones or formations of interest in a well to be drilled, logged and tested without the necessity of removing the drill string (18) from the well.

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PATENT SPECIFICATION

TITLE: DRILLING FORMATION TESTER, APPARATUS AND METHODS OF TESTING AND MONITORING STATUS OF TESTER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the drilling of oil and gas wells. In another aspect, the present invention relates to systems and methods for drilling well bores and evaluating subsurface zones of interest as the well bores are drilled into such zones. In even another aspect, the present invention relates to monitoring the operability of test equipment during the drilling process.

2. Description of the Related Art

It is well known in the subterranean well drilling and completion arts to perform tests on formations intersected by a wellbore. Such tests are typically performed in order to determine geological and other physical properties of the formations and fluids contained therein. For example, by making appropriate measurements, a formation's permeability and porosity, and the fluid's resistivity, temperature, pressure, and bubble point may be determined. These and other characteristics of the formation and fluid contained therein may be determined by performing tests on the formation before the well is completed.

It is of considerable economic importance for tests such as those described hereinabove to be performed as soon as possible after the formation has been intersected by the wellbore. Early evaluation of the potential for profitable recovery of the fluid contained therein is very desirable. For example, such early evaluation enables completion operations to be planned more efficiently. In addition, it has been found that more accurate and useful information can be obtained if

testing occurs as soon as possible after penetration of the formation.

As time passes after drilling, mud invasion and filter cake buildup may occur, both of which may adversely affect testing. Mud invasion occurs when formation fluids are displaced by drilling mud or mud filtrate. When invasion occurs, it may become impossible to obtain a representative sample of formation fluids or at a minimum, the duration of the sampling period must be increased to first remove the drilling fluid and then obtain a representative sample of formation fluids. Similarly, as drilling fluid enters the surface of the wellbore in a fluid permeable zone and leaves its suspended solids on the wellbore surface, filter cake buildup occurs. The filter cakes act as a region of reduced permeability adjacent to the wellbore. Thus, once filter cakes have formed, the accuracy of reservoir pressure measurements decrease, affecting the calculations for permeability and produceability of the formation. Where the early evaluation is actually accomplished during drilling operations within the well, the drilling operations may also be more efficiently performed, since results of the early evaluation may then

be used to adjust parameters of the drilling operations. In this respect, it is known in the art to interconnect formation testing equipment with a drill string so that, as the wellbore is being drilled, and without removing the drill string from the wellbore, formations intersected by the wellbore may be periodically tested.

In typical formation testing equipment suitable for interconnection with a drill string during drilling operations, various devices or systems are provided for isolating a formation from the remainder of the wellbore, drawing fluid from the formation, and measuring physical properties of the fluid and the formation. Unfortunately, due to the constraints imposed by the necessity of interconnecting the equipment with the drill string, typical formation testing equipment is not suitable for use in these circumstances.

Typical formation testing equipment is unsuitable for use while interconnected with a drill string because they encounter harsh conditions in the wellbore during the drilling process that can age and degrade the formation testing equipment before and during the testing process. These harsh conditions include vibration from the drill bit, exposure to drilling mud and formation

fluids, hydraulic forces of the circulating drilling mud, and scraping of the formation testing equipment against the sides of the wellbore.

Drill strings can extend thousands of feet underground. Testing equipment inserted with the drill string into the wellbore can therefore be at great distances from the earth's surface (surface). Therefore, testing equipment added to the drill string at the surface is often in the wellbore for days during the drilling process before reaching geologic formations to be tested. Also if there is a malfunction in testing equipment, removing the equipment from a well bore for repair can take a long time.

To determine the functional status or "health" of formation testing equipment designed to be used during the drilling process, one technique is to deploy and operate the testing equipment at time intervals prior to reaching formations to be tested. These early test equipment deployments to evaluate their status can expose that equipment to greater degradation in the harsh wellbore environment than without early deployment. It is well known in the art of logging-while-drilling (LWD) how to communicate from the surface to formation testing

equipment in the wellbore. Such testing equipment can be turned on and off from the surface and data collected by the testing equipment can be communicated to the surface. A common method of communication between testing equipment in the wellbore and the surface is through pressure pulses in the drilling mud circulating between the testing equipment and the surface.

Another problem faced using formation test equipment on a drill string far down a wellbore is to ensure that a series of steps in a test sequence are carried out in the proper sequence at the proper time. Communication from the earth's surface to formation testing equipment far down a well by drilling mud pulse code can take a relatively long time. Also, mud pulse communication can be confused by other equipment-caused pulses and vibrations in the drilling mud column between the down-hole testing equipment and the earth's surface.

However, in spite of the above advancements, there still exists a need in the art for apparatus and methods for a way to monitor the functional status or health of the formation testing equipment prior to its use without deploying the system.

There is another need in the art for apparatus and methods for identifying early component failures in the formation testing equipment that can cause subsequent component failures that hide early precipitating failures, which do not suffer from the disadvantages of the prior art apparatus and methods. There is even another need in the art for apparatus and methods for accomplishing test sequences by formation testing equipment down-hole automatically upon an initiating signal from the earth's surface.

These and other needs in the art will become apparent to those of skill in the art upon review of this specification, including its drawings and claims.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide for an integrated well drilling and evaluation system for drilling and logging a well and testing in an uncased well bore portion of the well. Generally the system comprises a drill string, a drill bit for drilling the well bore, wherein the drill bit is carried on a lower end of the drill string. Also, there is a logging while drilling apparatus, supported by said drill string, that during drilling and logging will generate data indicative of the nature of subsurface formations intersected by the uncased well bore, so that a formation or zone of interest may be identified without removing the drill string from a well. There is a packer, carried on said drill string above said drill bit, having a set position for sealingly closing a well annulus between the drill string and the uncased well bore above the formation or zone of interest and having an unset position such that the drill bit may be rotated to drill the well bore, the packer being selectively positionable between the set position and the unset position. There is a tester, inserted in the drill string, for controlling flow of fluid between the formation and the drill string when the

packer is in the set position. There is a function timer, included in the drill string, that during drilling and testing will control the operation of at least one of the logging while drilling apparatus, the packer, and the tester, whereby, the well can be selectively drilled, logged and tested without removing the drill string from the well.

It is another object of the present invention to provide for an integrated drilling and evaluation system for drilling and logging a well and testing in an uncased well bore of the well, comprising a drill string, a drill bit, carried on a lower end of the drill string, for drilling the well bore, a packer, carried on the drill string above the drill bit, for sealing a well annulus between the drill string and the uncased well bore above the drill bit means. There is a surge receptacle included in the drill string, a surge chamber means, constructed to mate with said surge receptacle, for receiving and trapping a sample of well fluid therein and a retrieval means for retrieving the surge chamber back to a surface location while the drill string remains in the uncased well bore. There is a logging while drilling means, included in the drill string, for generating data

indicative of the nature of subsurface zones or formations intersected by the uncased well bore. There is a circulating valve included in said drill string above said surge receptacles, and a function timer, included in the drill string, that during drilling and testing will control the operation of at least one of the logging while drilling apparatus, the packer, and the tester.

It is even another object of the present invention to provide for an integrated drilling and evaluation system for drilling and logging a well and testing in an uncased well bore portion of the well, comprising a drill string, and a drill bit, carried on a lower end of the drill string, for drilling the well bore. There is a packer for sealing a well annulus between the drill string and the uncased well bore above the drill bit, the packer being selectively positionable between set and unset positions;

a valve, included in the drill string, for controlling the flow of fluid between the well bore below the packer and the drill string when the packer is in the set position. There is a logging while drilling means, included in the drill string, for logging subsurface

zones or formations intersected by the uncased well bore. There is a circulating valve included in the drill string above the valve and a function timer, included in the drill string, that during drilling and testing will control the operation of at least one of the logging while drilling apparatus, the packer, the valve, and the circulating valve.

It is still another object of the present invention to provide for a method of early evaluation of a well having an uncased well bore intersecting a subsurface zone or formation of interest, comprising providing a testing string in the well bore comprising a tubing string, a logging tool included in the tubing string; a packer carried on the tubing string, a fluid testing device included in the tubing string, and a function timer, included in the tubing string. The method further includes logging the well with the logging tool and thereby determining the location of the subsurface zone or formation of interest. The method also includes without removing the testing string from the well bore after the previous step, setting the packer in the well bore above the subsurface formation and sealing a well annulus between the testing string and the well bore; and

flowing a sample of well fluid from the subsurface formation below the packer to the fluid testing device, and controlling the operation of at least one of the logging tool, the packer, and the fluid testing device with the function timer.

It is yet another object of the present invention to provide for an integrated drilling and evaluation apparatus for drilling a well and testing in an uncased well bore of a well, comprising a drill string, a drill bit, carried on a lower end of the drill string, for drilling the well bore, a packer, carried on the drill string above the drill bit, for sealing against the uncased well bore when in a set position and thereby isolating at least a portion of a formation or zone of interest intersected by the well bore and for disengaging the uncased well bore when in an unset position, thereby allowing fluid flow between the packer and the uncased well bore when the drill bit is being used for drilling the well bore. There is a fluid monitoring system, included in the drill string, for determining fluid parameters of fluid in the formation or zone of interest. There also is a tester valve, included in the drill string, for controlling flow of fluid from the formation

or zone of interest into the drill string when the packer is in the set position. And, there is a function timer, included in the drill string, that during drilling and testing will control a sequence of operation of at least one of the fluid monitoring system, the packer, and the tester valve, wherein, the well can be selectively drilled and tested without removing the drill string from the well.

It is even still another object of the present invention to provide a method of early evaluation of a well having an uncased well bore, comprising the steps of providing a drilling and testing string comprising a drill bit, a packer for sealingly engaging the well bore, which packer operates through a sequence of packer operational steps,a well fluid condition monitor, which monitor operates through a sequence of monitor operational steps, anda function timer. The method further comprises drilling the well bore with the drill bit until the well bore intersects a formation or zone of interest. The method even further comprises, without removing the drilling and testing string from the well after the previous step, effecting a seal with the packer against the uncased well bore and thereby isolating at

least a portion of the formation or zone of interest. The method even further comprises, without removing the drilling and testing string from the well bore, determining, with the well fluid condition monitor, fluid parameters of fluid in the formation or zone of interest. The method still further comprises, without removing the drilling and testing string from the well, controlling a sequence of operation of at least one of the packer, and the well fluid condition monitor.

These and other objects of the present invention will become apparent to those of skill in the art upon review of this specification, including its drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A-1D provide a sequential series of illustrations in elevation which are sectioned, schematic formats showing the drilling of a well bore and the periodic testing of zones or formations of interest therein in accordance with the present invention.

FIGS. 2A-2C comprise a sequential series of illustrations similar to FIGS. 1A-1C showing an alternative embodiment of the apparatus of this invention.

FIGS. 3 is a schematic illustration of another alternative embodiment of the apparatus of this invention.

FIG. 4 is a schematic illustration of an electronic remote control system for controlling various tools in the drill string from a surface control station.

FIG. 5 is a schematic illustration similar to FIG. 4 which also illustrates a combination inflatable packer and closure valve.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings, and particularly to FIGS. 1A-1D, the apparatus and methods of the present invention are schematically illustrated.

A well 10 is defined by a well bore 12 extending downwardly from the earth's surface 14 and intersecting a first subsurface zone or formation of interest 16. A drill string 18 is shown in place within the well bore 12. The drill string 18 basically includes a coiled tubing or drill pipe string 20, a tester valve 22, packer means 24, a well fluid condition monitoring means 26, a logging while drilling means 28 and a drill bit 30.

The tester valve 22 may be generally referred to as a tubing string closure means for closing the interior of drill string 18 and thereby shutting in the subsurface zone or formation 16.

The tester valve 22 may, for example, be a ball-type tester valve as is illustrated in the drawings. However, a variety of other types of closure devices may be utilized for opening and closing the interior of drill string 18. One such alternative device is illustrated and described below with regard to FIGURE 5. The packer means 24 and tester valve 22 may be operably associated so that the valve 22 automatically closes when the packer means 24 is set to seal the uncased well bore 12. For

example, the ball-type tester valve 22 may be a weight set tester valve and have associated therewith an inflation valve communicating the tubing string bore above the tester valve with the inflatable packer element 32 when the closure valve 22 moves from its open to its closed position. Thus, upon setting down weight to close the tester valve 22, the inflation valve communicated with the packer element 32 is opened and fluid pressure within the tubing string 20 may be increased to inflate the inflatable packer element 32. Other arrangements can include a remote controlled packer and tester valve which are operated in response to remote command signals such as is illustrated below with regard to FIG. 5.

As will be understood by those skilled in the art, various other arrangements of structure can be used for operating the tester valve 22 and packer element 24. For example, both the valve and packer can be weight operated so that when weight is set down upon the tubing string, a compressible expansion-type packer element is set at the same time that the tester valve 22 is moved to a closed position.

The packer means 24 carries and expandable packer element 32 for sealing a well annulus 34 between the tubing string 18 and the well bore 12. The packing element 32 may be either a compression type packing

element or an inflatable type packing element. When the packing element 32 is expanded to a set position as shown in FIGURE 1B, it seals the well annulus 34 therebelow adjacent the subsurface zone or formation 16. The subsurface zone or formation 16 communicates with the interior of the testing string 18 through ports (not shown) present in the drill bit 30.

The well fluid condition monitoring means 26 contains instrumentation for monitoring and recording various well fluid perimeters such as pressure and temperature. It may for example be constructed in a fashion similar to that of Anderson et al., U.S. Patent No. 4,866,607, assigned to the assignee of the present invention. The Anderson et al. device monitors pressure and temperature and stores it in an on board recorder. That data can then be recovered when the tubing string 18 is removed from the well. Alternatively, the well fluid condition monitoring means 26 may be a Halliburton RT-91 system which permits periodic retrieval of data from the well through a wire line with a wet connect coupling which is lowered into engagement with the device 26. This system is constructed in a fashion similar to that shown in U.S. Patent No. 5,236,048 to Skinner et al., assigned to the assignee of the present invention. Another alternative monitoring system 26 can provide

constant remote communication with a surface command station (not shown) through mud pulse telemetry or other remote communication system, as further described hereinbelow.

The logging while drilling means 28 is of a type known to those skilled in the art which contains instrumentation for logging subterranean zones or formations of interest during drilling. Generally, when a zone or formation of interest has been intersected by the well bore being drilled, the well bore is drilled through the zone or formation and the formation is logged while the drill string is being raised whereby the logging while drilling instrument is moved through the zone or formation of interest.

The logging while drilling tool may itself indicate that a zone or formation of interest has been intersected. Also, the operator of the drilling rig may independently become aware of the fact that a zone or formation of interest has been penetrated. For example, a drilling break may be encountered wherein the rate of drill bit penetration significantly changes. Also, the drilling cuttings circulating with the drilling fluid may indicate that a petroleum-bearing zone or formation has been intersected.

The logging while drilling means 28 provides constant remote communication with a surface command station by means of a remote communication system of a type described hereinbelow.

The drill bit 30 can be a conventional rotary drill bit and the drill string can be formed of conventional drill pipe. Preferably, the drill bit 30 includes a down hole drilling motor 36 for rotating the drill bit whereby it is not necessary to rotate the drill string. A particularly preferred arrangement is to utilize coiled tubing as the string 20 in combination with a steerable down hole drilling motor 36 for rotating the drill bit 30 and drilling the well bore in desired directions. When the drill string 18 is used for directional drilling, it preferably also includes a measuring while drilling means 37 for measuring the direction in which the well bore is being drilled. The measuring while drilling means 37 is of a type well known to those skilled in the art which provides constant remote communication with a surface command station.

Referring to FIGS. 1A-1D, and particularly FIG. 1A, the drill string 18 is shown extending through a conventional blow-out preventor stack 38 located at the surface 14. The drill string 18 is suspended from a conventional rotary drilling rig (not shown) in a well

known manner. The drill string 18 is in a drilling position within the well bore 12, and it is shown after drilling the well bore through a first subsurface zone of interest 16. The packer 18 is in a retracted position and the tester valve 22 is in an open position so that drilling fluids may be circulated down through the drill string 18 and up through the annulus 34 in a conventional manner during drilling operations.

During drilling, the well bore 12 is typically filled with a drilling fluid which includes various additives including weighting materials whereby there is an overbalanced hydrostatic pressure adjacent the subsurface zone 16. The overbalanced hydrostatic pressure is greater than the natural formation pressure of the zone 16 so as to prevent the well from blowing out.

After the well bore 12 has intersected the subsurface zone 16, and that fact has become known to the drilling rig operator as result of a surface indication from the logging while drilling tool 28 or other means, the drilling is continued through the zone 16. If it is desired to test the zone 16 to determine if it contains hydrocarbons which can be produced at a commercial rate, a further survey of the zone 16 can be made using the logging while drilling tool 28. As mentioned above, to

facilitate the additional logging, the drill string 20 can be raised and lowered whereby the logging tool 28 moves through the zone 16.

Thereafter, a variety of tests to determine the hydrocarbon production capabilities of the zone 16 can be conducted by operating the tester valve 22, the packer means 24 and the well fluid condition monitoring means 26. Specifically, the packer 24 is set whereby the well annulus 34 is sealed and the tester valve 22 is closed to close the drill string 18, as shown in FIG. 1B. This initially traps adjacent the subsurface zone 16 the overbalance hydrostatic pressure that was present in the annulus 34 due to the column of drilling fluid in the well bore 12. The fluids trapped in the well annulus 34 below packer 24 are no longer communicated with the column of drilling fluid, and thus, the trapped pressurized fluids will slowly leak off into the surrounding subsurface zone 16, i.e., the bottom hole pressure will fall-off. The fall-off of the pressure can be utilized to determine the natural pressure of the zone 16 using the techniques described in our copending application entitled *Early Evaluation By Fall-Off Testing*, designated as attorney docket number HRS 91.225B1, filed concurrently herewith, the details of which are incorporated herein by reference. As will be

understood, the well fluid condition monitoring means 28 continuously monitors the pressure and temperature of fluids within the closed annulus 34 during the pressure fall-off testing and other testing which follows.

Other tests which can be conducted on the subsurface zone 16 to determine its hydrocarbon productivity include flow tests. That is, the tester valve 22 can be operated to flow well fluids from the zone 16 to the surface at various rates. Such flow tests which include the previously described draw-down and build-up tests, open flow tests and other similar tests are used to estimate the hydrocarbon productivity of the zone over time. Various other tests where treating fluids are injected into the zone 16 can also be conducted if desired.

Depending upon the particular tests conducted, it may be desirable to trap a well fluid sample without the necessity of flowing well fluids through the drill string to the surface. A means for trapping such a sample is schematically illustrated in FIG. 1C. As shown in FIG. 1C, a surge chamber receptacle 40 is included in the drill string 20 along with the other components previously described. In order to trap a sample of the well fluid from the subsurface zone 16, a surge chamber 42 is run on a wire line 44 into engagement with the surge chamber receptacle 40. The surge chamber 42 is

initially empty or contains atmospheric pressure, and when it is engaged with the surge chamber receptacle 40, the tester valve 22 is opened whereby well fluids from the subsurface formation 16 flow into the surge chamber 42. The surge chamber 42 is then retrieved with the wire line 44. The surge chamber 42 and associated apparatus may, for example, be constructed in a manner similar to that shown in U.S. Patent No. 3,111,169 to Hyde, the details of which are incorporated herein by reference.

After the subsurface zone 16 is tested as described above, the packer 24 is unset, the tester valve 22 is opened and drilling is resumed along with the circulation of drilling fluid through the drill string 20 and well bore 12.

FIG. 1D illustrates the well bore 12 after drilling has been resumed and the well bore is extended to intersect a second subsurface zone or formation 46. After the zone or formation 46 has been intersected, the packer 24 can be set and the tester valve 22 closed as illustrated to perform pressure fall-off tests, flow tests and any other tests desired on the subsurface zone or formation 46 as described above.

As will now be understood, the integrated well drilling and evaluation system of this invention is used to drill a well bore and to evaluate each subsurface zone

or formation of interest encountered during the drilling without removing the drill string from the well bore. Basically, the integrated drilling and evaluation system includes a drill string, a logging while drilling tool in the drill string, a packer carried on the drill string, a tester valve in the drill string for controlling the flow of fluid into or from the formation of interest from or into the drill string, a well fluid condition monitor for determining conditions such as the pressure and temperature of the well fluid and a drill bit attached to the drill string. The integrated drilling and evaluation system is used in accordance with the methods of this invention to drill a well bore, to log subsurface zones or formations of interest and to test such zones or formations to determine the hydrocarbon productivity thereof, all without moving the system from the well bore.

FIGS. 2A-2C are similar to FIGS. 1A-1C and illustrate a modified drill string 18A. The modified drill string 18A is similar to the drill string 18, and identical parts carry identical numerals. The drill string 18A includes three additional components, namely, a circulating valve 48, an electronic control sub 50 located above the tester valve 22 and a surge chamber

receptacle 52 located between the tester valve 22 and the packer 24.

After the packer element 24 has been set as shown in FIG. 2B, the tester valve 22 is closed and the circulating valve 94 is open whereby fluids can be circulated through the well bore 12 above the circulating valve 48 to prevent differential pressure drill string sticking and other problems.

The tester valve 22 can be opened and closed to conduct the various tests described above including pressure fall-off tests, flow tests, etc. As previously noted, with any of the tests, it may be desirable from time to time to trap a well fluid sample and return it to the surface for examination. As shown in FIG. 2C, a sample of well fluid may be taken from the subsurface zone or formation 16 by running a surge chamber 42 on a wire line 44 into engagement with the surge chamber receptacle 52. When the surge chamber 42 is engaged with the surge chamber receptacle 52, a passageway communicating the surge chamber 42 with the subsurface zone or formation 16 is opened so that well fluids flow into the surge chamber 42. The surge chamber 42 is then retrieved with the wire line 44. Repeated sampling can be accomplished by removing the surge chamber, evacuating it and then running it back into the well.

Referring now to FIG. 3 another modified drill string 18B is illustrated. The modified drill string 18B is similar to the drill string 18A of FIGS. 2A-2C, and identical parts carry identical numerals. The drill string 18B is different from the drill string 18A in that it includes a straddle packer 54 having upper and lower packer elements 56 and 57 separated by a packer body 59 having ports 61 therein for communicating the bore of tubing string 20 with the well bore 12 between the packer elements 56 and 57.

After the well bore 12 has been drilled and the logging while drilling tool 28 has been operated to identify the various zones of interest such as the subsurface zone 16, the straddle packer elements 56 and 57 are located above and below the zone 16. The inflatable elements 56 and 57 are then inflated to set them within the well bore 12 as shown in FIG. 3. The inflation and deflation of the elements 56 and 57 are controlled by physical manipulation of the tubing string 20 from the surface. The details of construction of the straddle packer 98 may be found in our copending application entitled *Early Evaluation System*, designated as attorney docket number HRS 91.225A1, filed concurrently herewith, the details of which are incorporated herein by reference.

The drill strings 18A and 18B both include an electronic control sub 50 for receiving remote command signals from a surface control station. The electronic control system 50 is schematically illustrated in FIG. 4. Referring to FIG. 4, electronic control sub 50 includes a sensor transmitter 58 which can receive communication signals from a surface control station and which can transmit signals and data back to the surface control station. The sensor/transmitter 58 is communicated with an electronic control package 60 through appropriate interfaces 62. The electronic control package 60 may for example be a microprocessor based controller. A battery pack 64 provides power by way of power line 66 to the control package 60.

The electronic control package 60 generates appropriate drive signals in response to the command signals received by sensor/transmitter 58, and transmits those drive signals over electric lines 68 and 70 to an electrically operated tester valve 22 and an electric pump 72, respectively. The electrically operated tester valve 22 may be the tester valve 22 schematically illustrated in FIGS. 2A-2C and FIG. 3. The electronically powered pump 72 takes well fluid from either the annulus 34 or the bore of tubing string 20 and

directs it through hydraulic line 74 to the inflatable packer 24 to inflate the inflatable element 32 thereof.

Thus, the electronically controlled system shown in FIG. 4 can control the operation of tester valve 22 and inflatable packer 24 in response to command signals received from a surface control station. Also, the measuring while drilling tool 37, the logging while drilling tool 28, the functional status monitor 27, the function timer 31, and the well fluid condition monitor 26 may be connected with the electronic control package 60 over electric lines 69, 71, 67, 73, and 76, respectively, and the control package 60 can transmit data generated by the measuring while drilling tool 37, the logging while drilling tool 28, the functional status monitor 27, the function timer 31 and the well fluid condition monitor 26 to the surface control station while the drill strings 18A and 18B remain in the well bore 12.

Functional status monitor 27 has at least three benefits: (1) it warns of system degradation, while still potentially operational; (2) it warns of test system problems that can put the entire drilling operation at risk; and (3) it identifies component failure.

While drilling formation tester (DFT) tools comprising tester valve 22, circulating valve 48, packers

32, 56 and 57 are in "sleep" or low power mode, functional status monitor 27 occasionally monitors sensors to check the functional status of the test system. A status bit can be sent to indicate that the tool has a change in functional status. Such a status message would alert an operator that a potential problem could occur. An attached LWD communication system would report the status bit change to the operator. The functional status monitor 27 may comprise independent electronics or may be part of the tool electronics. The status monitor 27 function includes sensors that monitor the system.

Depending upon the types of sensors utilized, the functional status monitor evaluates one or more of the following:

(1) hydraulic pressure to indicate hydraulic power system functional status;

(2) oil reserve volume to indicate leakage;

(3) circulating valve position to indicate false activation;

(4) circulating valve leakage to indicate washout possibility; and

(5) packer position to indicate inflation or attachment to borehole.

It should be understood that any suitable definition scheme can be utilized for assigning meaning to the information bits. As a non-limiting example, one possible system for assigning meaning to information bits is the following:

Bit 14: This bit identifies the meaning of following bits. If Bit 14 = 0 then Bits 13 to 00 represent pressure data (REPO) with a LSB value of 0.25 PSI. If Bit 14 = 1 the remaining bits represents DFT tool status (REST).

Bit 13: If this bit is set to 1 (in addition to bit 14=1 then bits 12 to 00 represent the minimum pressure (REPM) encountered during the draw down portion of the formation test with a LSB value of 0.5 PSI. Minimum pressure is only transmitted once during the build up period of the formation test.

Bit 12: If this bit is set to 1 (in addition to bit 14=1 then bits 11 to 04 represent draw down flow rate (REDQ) in cc/sec. The LSB value of this variable is 1 cc/sec.

Bit 11 & Bit 10: Bits 11 & 10 identify status of the hydraulic system as shown:

Bit 11	Bit 10	
0	0	Hydraulic Pressure Off
0	1	Hydraulic Pressure Low
1	0	Hydraulic Pressure OK
1	1	Hydraulic Pressure High

Bit 09: Identifies the Circulating valve function. A value of 0 indicates the Circulating valve is off (de-activated) while a 1 tells that the Circulating valve is activated.

Bit 08: Is the Circulating valve status. A value of 0 indicates the Circulating valve operated OK while a value of 0 shows the Circulating valve operation failed.

Bit 07: Identifies the Packer function. A value of 0 indicates the Packers are off (deflated) while a 1 shows that the Packers are activated.

<u>Bit 06</u>: This bit shows the packer status. A value of 0 indicates the Packers are OK. A value of 1 shows the Packer failed to inflate properly.

<u>Bit 05</u>: Identifies Draw Down function. A value of 0 indicates the Draw Down is off, a value of 1 shows the Draw Down function is on.

<u>Bit 04</u>: This bit shows the draw down status. A value of 0 shows the draw down is OK, a value of 1 shows the draw down failed.

<u>Bit 03</u>: Base Line Pressure (REBP) MSB

<u>Bit 02</u> Base Line Pressure (REBP)

<u>Bit 01</u> Base Line Pressure (REBP)

<u>Bit 00</u>: Base Line Pressure (REBP) LSB

Also shown in FIG. 4 is a function timer 31. Timer 31 acts to control the sequence of sampling steps of formation fluids after receiving an initiating signal from the earth's surface via sensor transmitter 58. Timer 31 controls the sequence and timing of activation and deactivation of circulating valve 48; packers 32, 56 and 57; and tester valve 22 for the purpose of collecting formation fluid samples from such a geologic formation as formation 16. Timer 31 activates circulating valve 48 above packers 32, 56, and 57 to circulate mud above the packers to prevent drill line sticking and allow mud pulse communication with the surface. Timer 31 then controls the inflation of packers 32 or 56 and 57 to isolate a portion of formation 16 face. Then timer 31

controls the activation of tester valve 22 to draw down test of formation fluid as previously described or to collect a sample of formation fluid for transport to the surface or storage in surge chamber 42.

FIG. 5 illustrates an electronic control sub 50 like that of FIG. 4 in association with a modified combined packer and tester valve means 80. The combination packer/closure valve 80 includes a housing 82 having an external inflatable packer element 84 and an internal inflatable valve closure element 86. An external inflatable packer inflation passage 88 defined in housing 82 communicates with the external inflatable packer element 84. A second inflation passage 90 defined in the housing 82 communicates with the internal inflatable valve closure element 86. As illustrated in FIG. 5, the electronic control sub 50 includes an electronically operated control valve 92 which is operated by the electronic control package 60 by way of an electric line 94. One of the outlet ports of the valve 92 is connected to the external inflatable packer element inflation passage 88 by a conduit 96, and the other outlet port of the valve 92 is connected to the internal inflatable valve closure inflation passage 90 by a conduit 98.

When fluid under pressure is directed through hydraulic conduit 96 to the passage 88, it inflates the

external packer elements to the phantom line positions 100 shown in FIG. 5 so that the external packer element 84 seals off the well annulus 34. When fluid under pressure is directed through the hydraulic conduit 98 to the passage 90, it inflates the internal valve closure element 86 to the phantom line positions 102 shown in FIG. 5 so that the internal inflatable valve closure element 86 seals off the bore of the drill string 18. When fluid under pressure is directed through both the conduits 96 and 98, both the external packer element 84 and internal valve element 86 are inflated. Thus, the electronic control sub 50 in combination with the packer and valve apparatus 80 can selectively set and unset the packer 84 and independently selectively open and close the inflatable valve element 86.

As will be understood, many different systems can be utilized to send command signals from a surface location down to the electronic control sub 50. One suitable system is the signaling of the electronic control package 60 of the sub 50 and receipt of feedback from the control package 60 using acoustical communication which may include variations of signal frequencies, specific frequencies, or codes of acoustic signals or combinations of these. The acoustical transmission media includes tubing string, electric line, slick line, subterranean

soil around the well, tubing fluid and annulus fluid. An example of a system for sending acoustical signals down the tubing string is disclosed in U.S. Patents Nos. 4,375,239; 4,347,900; and 4,378,850 all to Barrington and assigned to the assignee of the present invention. Other systems which can be utilized include mechanical or pressure activated signaling, radio wave transmission and reception, microwave transmission and reception, fiber optic communications, and the others which are described in U.S. Patent No. 5, 555,945 to Schultz et al., the details of which are incorporated herein by reference.

While the illustrative embodiments of the invention have been described with particularity, it will be understood that various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the spirit and scope of the invention. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the examples and descriptions set forth herein but rather that the claims be construed as encompassing all the features of patentable novelty which reside in the present invention, including all features which would be treated as equivalents thereof by those skilled in the art to which this invention pertains.

WE CLAIM:

1. An integrated well drilling and evaluation system for drilling and logging a well and testing in an uncased well bore portion of the well, comprising:

a drill string;

a drill bit, carried on a lower end of said drill string, for drilling the well bore;

logging while drilling apparatus, supported by said drill string, that during drilling and logging will generate data indicative of the nature of subsurface formations intersected by said uncased well bore, so that a formation or zone of interest may be identified without removing said drill string from said well;

a packer, carried on the drill string above the drill bit, having a set position for sealingly closing a well annulus between said drill string and said uncased well bore above the formation or zone of interest and having an unset position such that said drill bit may be rotated to drill said well bore, the packer being selectively positionable between said set position and said unset position;

a tester, inserted in said drill string, for controlling flow of fluid between said formation and said

drill string when said packer is in said set position; and

a function timer, included in said drill string, that during drilling and testing will control the operation of at least one of the logging while drilling apparatus, the packer, and the tester;

whereby, said well can be selectively drilled, logged and tested without removing said drill string from said well.

2. The system of claim 1, further comprising:

a circulating valve, included in said drill string above said tester.

3.The system of claim 1, wherein:

said tester includes a closure valve for communicating said formation of interest with the interior of said drill string.

4. The system of claim 1, wherein said tester comprises:

a surge receptacle included in said drill string;

a surge chamber , constructed to mate with said surge receptacle, for receiving and trapping a sample of said well fluid therein; and

retrieval means for retrieving said surge chamber back to a surface location while said drill string remains in said well bore.

5. The system of claim 1, further comprising:

a downhole drilling motor, included in said drill string and operably associated with said drill bit, for rotating said drill bit to drill said well bore.

6. The system of claim 5, wherein said downhole drilling motor is a steerable downhole drilling motor.

7. The system of claim 5, further comprising:

measuring while drilling means, included in said drill string, for measuring a direction of said well bore.

8. The system of claim 1, further comprising:

monitoring means for monitoring a parameter of said well fluid.

9. The system of claim 1, wherein said packer includes a straddle packer.

10. The system of claim 1, wherein said packer includes an inflatable packer.

11. The system of claim 1, wherein:

said drill string is a coiled tubing drill string.

12. The system of claim 1, further comprising a functional status monitor, included in said drill string, comprising sensors in communication with at least one of the logging while drilling apparatus, the packer, and the tester.

13. An integrated drilling and evaluation system for drilling and logging a well and testing in an uncased well bore of the well, comprising:

a drill string;

a drill bit, carried on a lower end of said drill string, for drilling the well bore;

a packer, carried on said drill string above said drill bit, for sealing a well annulus between said drill string and said uncased well bore above said drill bit means;

a surge receptacle included in said drill string;

surge chamber means, constructed to mate with said surge receptacle, for receiving and trapping a sample of well fluid therein;

retrieval means for retrieving said surge chamber back to a surface location while said drill string remains in said uncased well bore;

logging while drilling means, included in said drill string, for generating data indicative of the nature of subsurface zones or formations intersected by said uncased well bore;

a circulating valve included in said drill string above said surge receptacles; and

a function timer, included in said drill string, that during drilling and testing will control the operation of at least one of the logging while drilling apparatus, the packer, and the tester.

14. The system of claim 13, further comprising:

measuring while drilling means, included in said drill string, for measuring a direction of said well bore.

15. The system of claim 13, further comprising:

pressure and temperature monitoring means for measuring and recording pressure and temperature data for said well fluid.

16. The system of claim 13, further comprising a function status monitor, included in said drill string, comprising sensors in communication with at least one of the logging while drilling apparatus, the packer, and the tester.

17. An integrated drilling and evaluation system for drilling and logging a well and testing in an uncased well bore portion of the well, comprising:

a drill string;

a drill bit, carried on a lower end of said drill string, for drilling said well bore;

a packer for sealing a well annulus between

said drill string and said uncased well bore above said drill bit, said packer being selectively positionable between set and unset positions;

a valve, included in said drill string, for controlling the flow of fluid between said well bore below said packer and said drill string when said packer is in said set position;

logging while drilling means, included in said drill string, for logging subsurface zones or formations intersected by said uncased well bore;

a circulating valve included in said drill string above said valve; and

a function timer, included in said drill string, that during drilling and testing will control the operation of at least one of the logging while drilling apparatus, the packer, the valve, and the circulating valve.

18. The system of claim 17, further comprising:

measuring while drilling means, included in said drill string, for measuring a direction of said well bore.

19. The system of claim 17, further comprising:

well fluid condition monitoring means for measuring and recording pressure and temperature data for said well fluid.

20. The system of claim 17, wherein said drill string is a coiled tubing drill string.

21. The system of claim 17, further comprising:

downhole motor for rotating said drill bit.

22. The system of claim 17, wherein said packer includes a straddle packer.

23. The system of claim 17, further comprising a function status monitor, included in said drill string, comprising sensors in communication with at least one of the logging while drilling apparatus, the packer, and the tester.

24. A method of early evaluation of a well having an uncased well bore intersecting a subsurface zone or formation of interest, comprising:

(a) providing a testing string in said well bore comprising:

a tubing string;

a logging tool included in said tubing string;

a packer carried on said tubing string;

a fluid testing device included in said tubing string; and

a function timer, included in said tubing string;

(b) logging said well with said logging tool and thereby determining the location of said subsurface zone or formation of interest;

(c) without removing said testing string from said well bore after step (b), setting said packer in said well bore above said subsurface formation and sealing a well annulus between said testing string and said well bore; and

(d) flowing a sample of well fluid from said subsurface formation below said packer to said fluid testing device;

(e) controlling the operation of at least one

of the logging tool, the packer, and the fluid testing device with the function timer.

25. The method of claim 24, wherein the drill string further comprises a function status monitor, the method further comprising:

(f) monitoring the status of at least one of the logging tool, the packer, and the fluid testing device, with the function status monitor.

26. The method of claim 25, wherein:

in step (a), said testing string is a drill string further including a drill bit carried on a lower end of said drill string;

step (a) includes drilling said well bore with said drill bit; and

step (b) is performed without removing said drill string from said well bore after said drilling step.

27. The method of claim 25, wherein:

in step (a), said drill string further includes a steerable downhole drilling motor and a measuring while

drilling too;

step (a) includes rotating said drill bit with said steerable downhole drilling motor to drill said well bore; and

said method further comprises:

measuring a direction of said well bore with said measuring while drilling tool.

28. The method of claim 25, wherein:

in step (a), said drill string further includes:

a circulating valve located above said fluid testing device; and

said fluid testing device is a flow tester valve for controlling flow of well fluid through said tubing string; and

step (d) includes opening said flow tester valve and flowing said sample of said well fluid up through said drill string to a surface location to flow test said well.

29. The method of claim 28, wherein:

in step (a), said fluid testing device includes

a surge receptacle included in said drill string and a surge chamber constructed to mate with said surge receptacle; and

step (d) includes:

running said surge chamber into said drill string;

mating said surge chamber with said surge receptacle;

flowing said fluid sample into said surge chamber; and

retrieving said surge chamber while said drill string remains in said well bore.

30. The method of claim 29, wherein:

in step (a) said drill string further includes a circulating valve located above said fluid testing device; and

said method further comprises during step (d):

opening said circulating valve; and

circulating fluid through said well annulus above said packer to prevent differential sticking of said tubing string in said open well bore.

31. An integrated drilling and evaluation apparatus for drilling a well and testing in an uncased well bore of a well, comprising:

a drill string;

a drill bit, carried on a lower end of the drill string, for drilling the well bore;

a packer, carried on the drill string above the drill bit, for sealing against the uncased well bore when in a set position and thereby isolating at least a portion of a formation or zone of interest intersected by the well bore and for disengaging the uncased well bore when in an unset position, thereby allowing fluid flow between the packer and the uncased well bore when the drill bit is being used for drilling the well bore;

a fluid monitoring system, included in the drill string, for determining fluid parameters of fluid in the formation or zone of interest;

a tester valve, included in the drill string, for controlling flow of fluid from the formation or zone of interest into the drill string when the packer is in the set position; and

a function timer, included in said drill

string, that during drilling and testing will control a sequence of operation of at least one of the fluid monitoring system, the packer, and the tester valve;

wherein, the well can be selectively drilled and tested without removing the drill string from the well.

32. The apparatus of claim 31, comprising:

a functional status monitor, included in said drill string, comprising sensors in communication with at least one of the fluid monitoring system, the packer, and the tester valve.

33. The apparatus of claim 31, wherein the tester valve comprises a closure valve for communicating the formation or zone of interest with an interior portion of the drill string.

34. The apparatus of claim 31, further comprising:

a surge receptacle included in the drill string; and

a retrievable surge chamber, constructed to mate with the surge receptacle, for receiving and

trapping a sample of well fluid therein.

35. The apparatus of claim 31, further comprising: a downhole drilling motor, included in the drill string and operatively associated with the drill bit, for rotating the drill bit to drill the well bore.

36. The apparatus of claim 35, wherein the downhole drilling motor is steerable.

37. The apparatus of claim 35, further comprising a measuring while drilling system, included in the drill string, for measuring a direction of the well bore as the drill bit is rotated.

38. The apparatus of claim 31, wherein: the drill string is a coiled tubing drill string.

39. The apparatus of claim 31 wherein the fluid monitoring system is adapted for selectively measuring temperature and pressure of the fluid.

40. The apparatus of claim 31 further comprising a logging while drilling tool, included in the drill string, for generating data indicative of the nature of subsurface formations or zones of interest intersected by the well bore.

41. The apparatus of claim 31 wherein:

the set position of the packer sealingly engages the uncased well bore and thereby seals a well annulus between the drill string and the uncased well bore above the formation or zone of interest; and

the unset position is disengaged from the uncased well bore and allows fluid flow through the annulus when the drill bit is drilling the well bore.

42. The apparatus of claim 31 wherein:

the packer is a straddle packer for sealing on opposite sides of the formation or zone of interest.

43. The apparatus of claim 31, wherein:

the packer is an inflatable packer.

44. The apparatus of claim 31 wherein:

the fluid monitoring system provides remote communication with a surface command station through telemetry.

45. A method of early evaluation of a well having an uncased well bore, comprising the steps of:

(a) providing a drilling and testing string comprising:

a drill bit;

a packer for sealingly engaging the well bore, which packer operates through a sequence of packer operational steps;

a well fluid condition monitor, which monitor operates through a sequence of monitor operational steps; and

a function timer;

(b) drilling the well bore with the drill bit until the well bore intersects a formation or zone of interest;

(c) without removing the drilling and testing string from the well after step (b), effecting a seal with the packer against the uncased well bore and thereby

isolating at least a portion of the formation or zone of interest;

(d) without removing the drilling and testing string from the well bore, determining, with the well fluid condition monitor, fluid parameters of fluid in the formation or zone of interest; and

(e) without removing the drilling and testing string from the well, controlling a sequence of operation of at least one of the packer, and the well fluid condition monitor.

46. The method of claim 45, wherein

(f) without removing the drilling and testing string from the well, determining whether at least one of the packer and well fluid condition monitors are functioning within acceptable parameters.

47. The method of claim 45 wherein step (d) comprises flowing fluid from the formation or zone of interest into the drilling and testing string.

48. The method of claim 47, wherein:

in step (a), the drilling and testing string

further comprises a fluid testing device; and

the step of flowing fluid comprises flowing a sample of fluid from the subsurface formation or zone of interest to the well testing device.

49. The method of claim 48, wherein:

in step (a), the drilling and testing string further comprises a circulating valve located above the fluid testing device;

the fluid testing device is a flow tester valve for controlling flow of well fluid through the tubing string; and

step (d) further comprises opening the flow tester valve and flowing the sample of well fluid up through the drilling and testing string to a surface location to flow test the well.

50. The method of claim 47, wherein:

in step (a), the drilling and testing string comprises a surge receptacle; and

the step of flowing fluid comprises:

running a surge chamber constructed to

mate with the surge receptacle into the drilling and testing string;

mating the surge chamber with the surge receptacle;

flowing fluid from the surge chamber; and

retrieving the surge chamber while the drilling and testing string remains in the well bore.

51. The method of claim 50, wherein:

in step (a), the drilling and testing string further comprises a circulating valve located above the well fluid testing device; and

said method further comprises:

(g) opening the circulating valve; and

(h) circulating fluid above the packer to prevent differential sticking of the drilling and testing string in the uncased well bore.

52. The method of claim 51 wherein steps (g) and (h) are carried out during step (d).

53. The method of claim 45 wherein step (d) is carried out after steps (b) and (c).

54. The method of claim 45 wherein the step of determining fluid parameters comprises determining a pore pressure of the formation or zone of interest.

55. The method of claim 45 wherein the step of determining fluid parameters comprises determining a temperature of the fluid.

56. The method of claim 45, wherein:

in step (a), the drilling and testing string further comprises a steerable downhole drilling motor; and

step (b) further comprises rotating the drill bit with the downhole steerable drilling motor.

57. The method of claim 56, wherein:

in step (a), the drilling and testing string further comprises a measuring while drilling tool; and

step (b) further comprises measuring a

direction of the well bore with the measuring while drilling tool.

58. The method of claim 45, wherein:

in step (a), the drilling and testing string further comprises a logging tool; and

step (b) further comprises logging the well with the logging tool to determine the location of the formation or zone of interest.

59. The method of claim 45, wherein:

step (c) comprises setting the packer in the uncased well bore adjacent the formation or zone of interest and sealing a well annulus between the drilling and testing string and the uncased well bore.

60. The method of claim 59, wherein:

the packer is a straddle packer having spaced packer elements thereon; and

step (c) comprises setting the straddle packer in the uncased well bore such that the portion of the formation or zone of interest is between the packer elements of the packer.

1/4

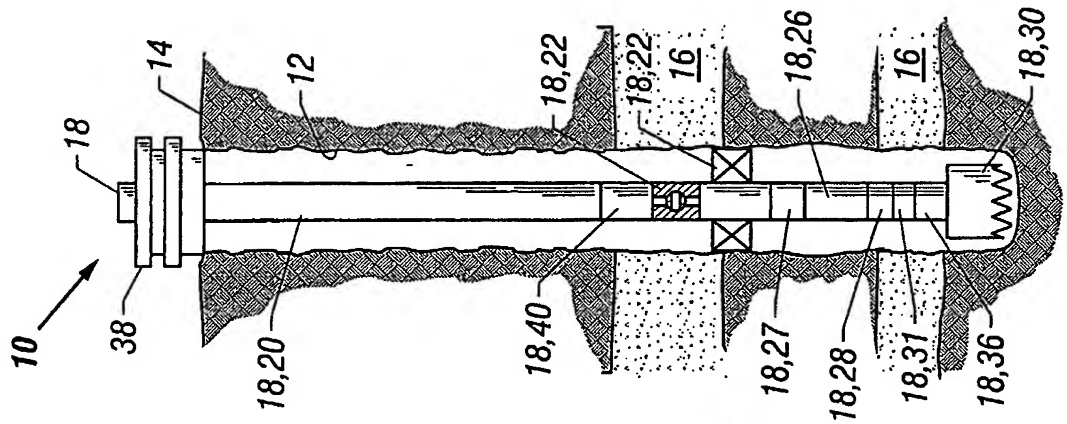

FIG. 1D

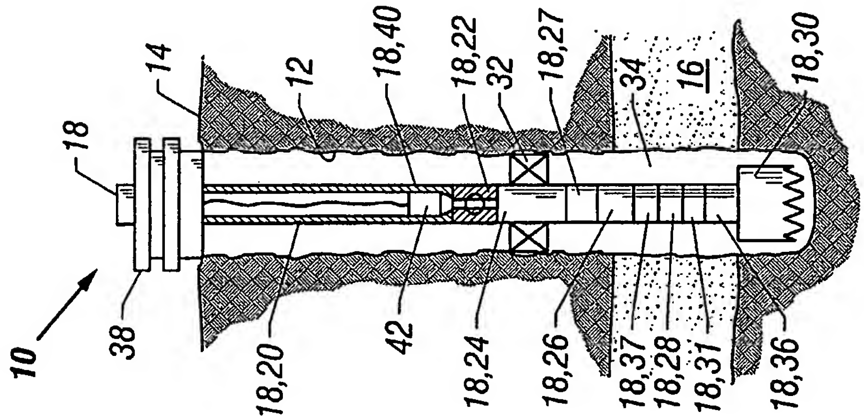

FIG. 1C

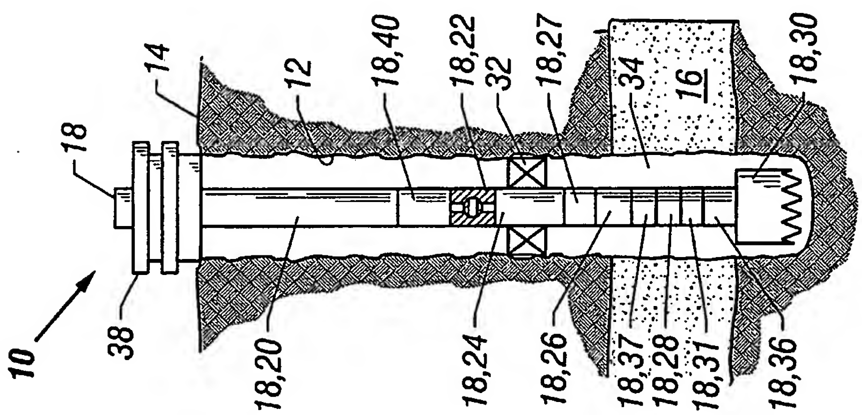

FIG. 1B

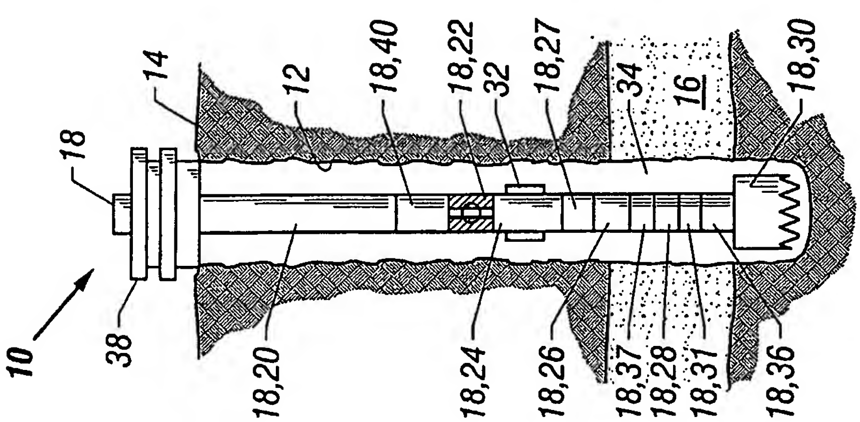

FIG. 1A

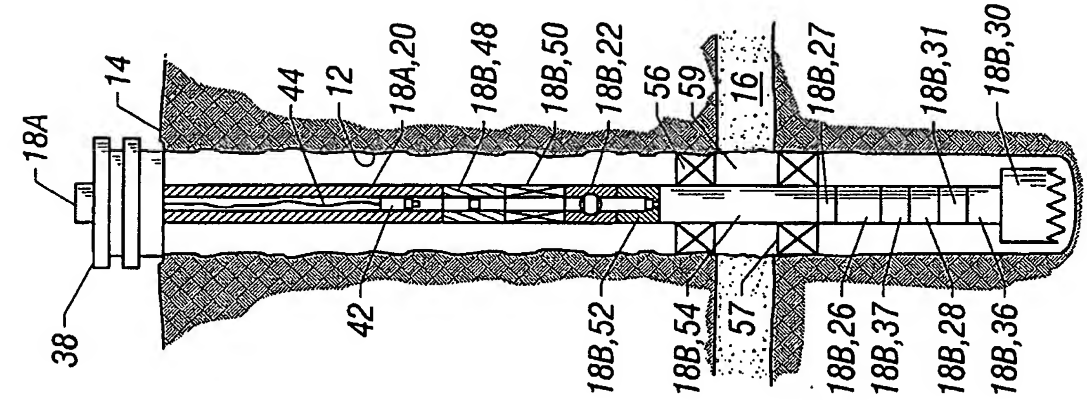

FIG. 3

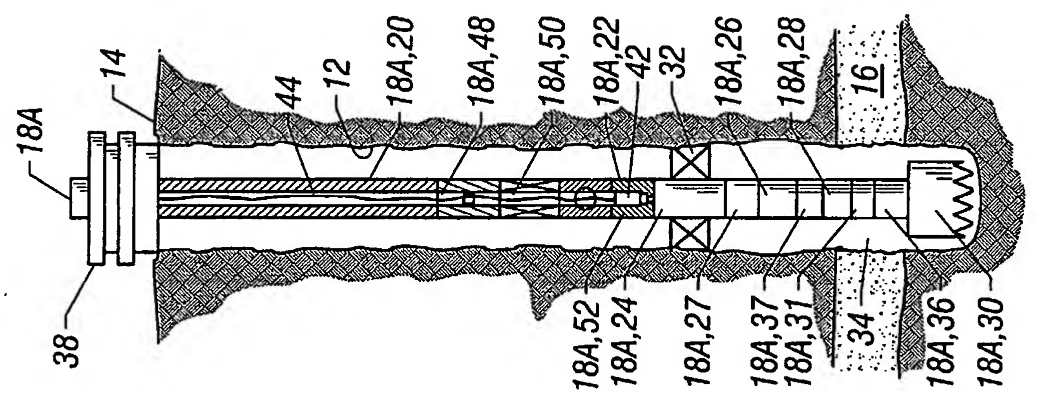

FIG. 2C

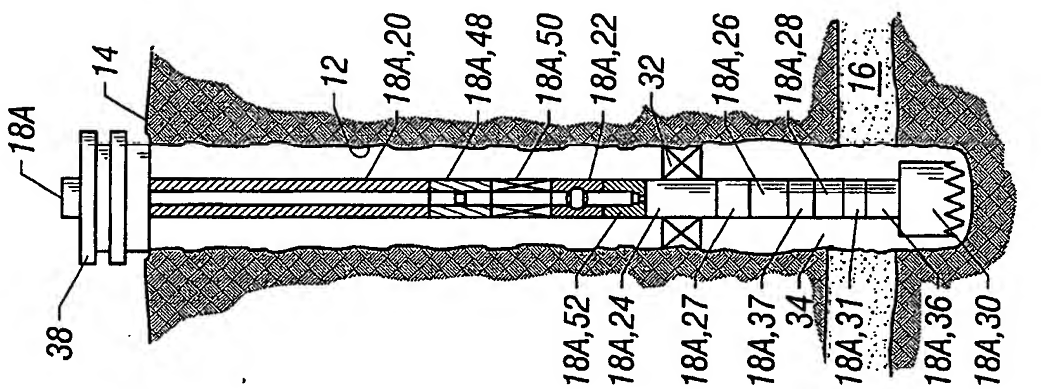

FIG. 2B

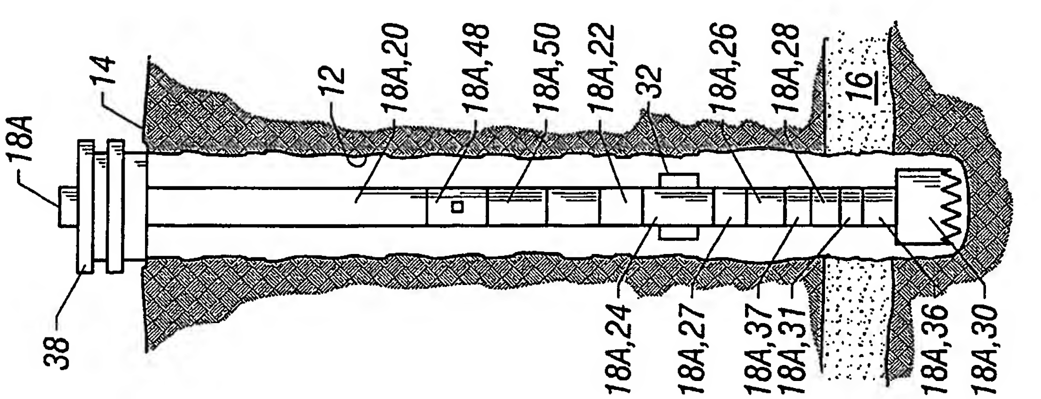

FIG. 2A

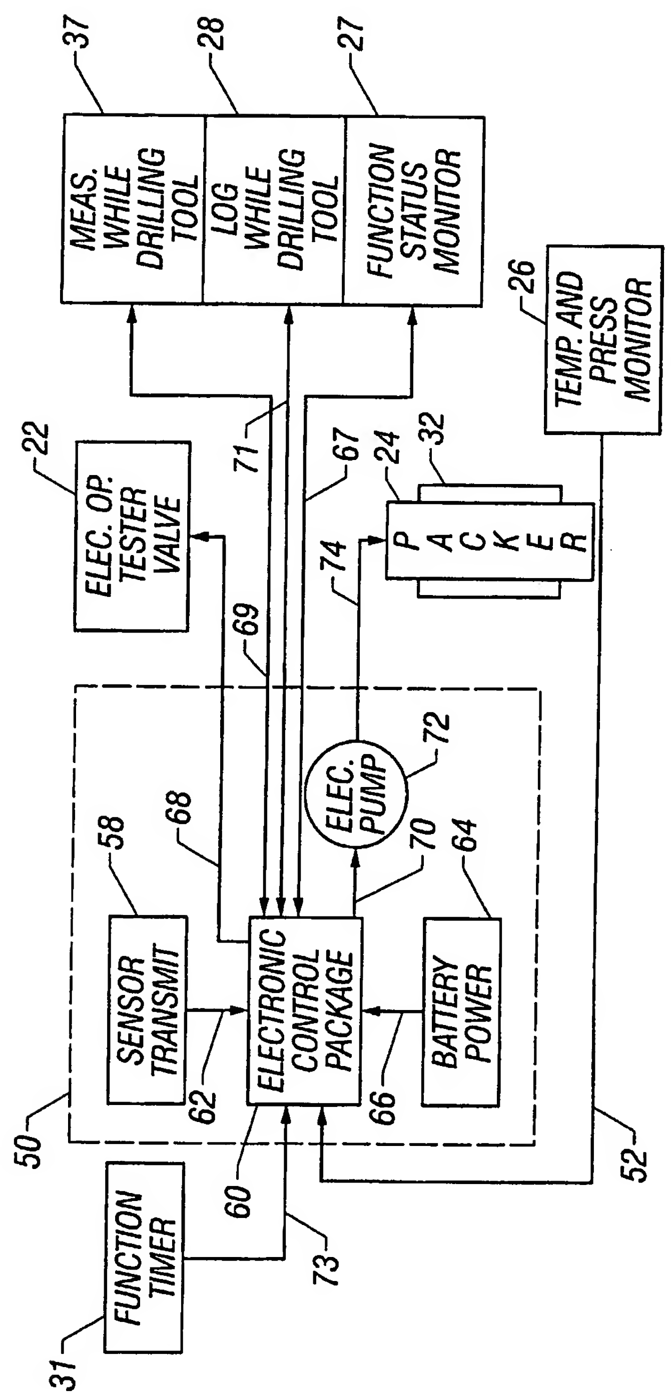
MEAS. WHILE DRILLING TOOL
LOG WHILE DRILLING TOOL
FUNCTION STATUS MONITOR
TEMP. AND PRESS MONITOR
ELEC. OP. TESTER VALVE
PACKER
ELEC. PUMP
SENSOR TRANSMIT
ELECTRONIC CONTROL PACKAGE
BATTERY POWER
FUNCTION TIMER
37
28
27
26
22
71
67
24
32
74
69
72
58
68
70
64
62
66
50
60
52
73
31

FIG. 4

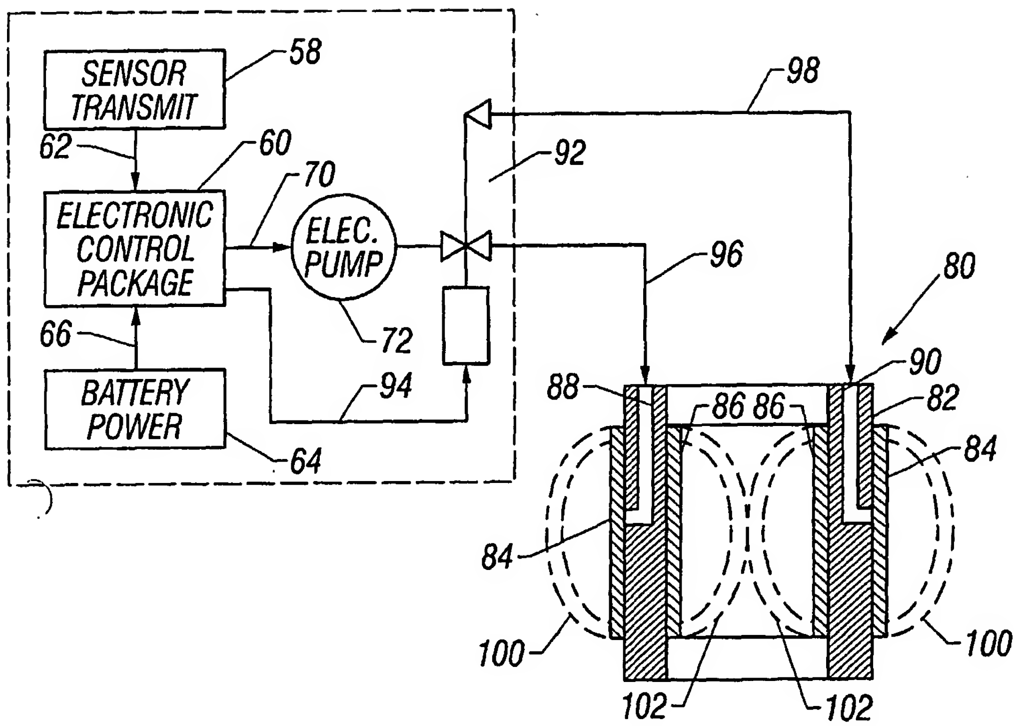
SENSOR TRANSMIT
58
62
60
ELECTRONIC CONTROL PACKAGE
70
ELEC. PUMP
72
66
BATTERY POWER
64
94
92
98
96
80
88
90
86 86
82
84
84
100
100
102
102

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/30597

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : E21B 47/00, 49/08
US CL : 175/48, 50; 73/ 152.03, 152.46
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 175/48, 50, 59; 73/ 152.03, 152.43, 152.46; 166/ 66, 250.01, 250.07, 250.17, 254.2

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,881,406 A (COURY) 21 November 1989 (21.11.89), abstract; figure 1; column 8, lines 5-32; claims 1-3.	1-60
Y	US 5,803,186 A (BERGER et al.) 08 September 1998 (08.09.98), figures 1 and 3; claims 1-8.	1-60
Y	US RE 35,790 A (PUSTANYK et al.) 12 May 1998 (12.05.98), abstract.	6, 27,36, 56
Y	US 5,679,894 A (KRUGER et al.) 21 October 1997 (21.10.97), abstract; figures 1 and 2; column 5, line 5-column 9, line 12.	7, 12, 14, 16, 18, 23, 25-30, 32, 37, 46, 57
A	US 5,484,029 A (EDDISON) 16 January 1996 (16.01.96), see entire document.	1-60
A	US 5,103,906 A (SCHULTZ et al.) 14 April 1992 (14.04.92), see entire document.	1-60
A	US 4,405,021 A (MUMBY) 20 September 1983 (20.09.83), see entire document.	1-60
A	EP 0 553 908 A2 (ORBAN) 04 August 1993 (04.08.93), see entire document.	1-60

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 11 January 2001 (11.01.2001)	Date of mailing of the international search report 19 MAR 2001
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer David Bagnell Diane Smith for Telephone No. (703) 308-1113